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FIELD STUDIES OF IMPREGNATED CONCRETE PIPE

by

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16. ABSTRACT

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DISCLAIMER

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ABSTRACT

This program was undertaken as a follow-on to two previous studies sponsored by the U.S. Environmental Protection Agency at Southwest Research Institute. The first study was initiated in 1970 as a laboratory study to investigate low-cost impregnants for concrete sewer pipe to improve corrosion resistance and strength. In the second program, initiated in 1974, 1400 ft (427 m) of concrete pipe was impregnated and installed in several Texas cities.

This follow-on program was initiated in June 1980 to continue monitoring the performance of those installed lines. Of principal interest at the sites in Harlingen, Dallas, and Beaumont has been the performance of concrete pipe as compared to sulfur-impregnated concrete pipe; hydrofluoric acid (HF)-treated concrete pipe; double-treated pipe using HF and sulfur; and other pipe, including ductile iron and PVC plastic.

The measured corrosion rates ranged from 0.12 in. (0.3 cm) to 0.51 in. (1.3 cm) for the 10-year period. The corrosion rates varied significantly among the sites tested and the pipe treatments evaluated.

This report is submitted in fulfillment of Cooperative Agreement No. CR807356010 by Southwest Research Institute under sponsorship of the U.S. Environmental Protection Agency. The time period of this report extends from June 1980 to June 1985, and work was completed in March of 1985.

1. INTRODUCTION

This program was initiated in June 1980 as a follow-on to two previous U.S. Environmental Protection Agency programs to produce low-cost, impregnated concrete sewer pipe with improved corrosion resistance. The first program was initiated in 1970 as a laboratory research program at Southwest Research Institute (SwRI), wherein over 100 different types of materials were screened as potential low-cost impregnants for concrete pipe. As a result of that first study, two materials, dilute hydrofluoric acid (HF) and sulfur, were found that drastically improved the corrosion resistance of concrete. Additionally, it was found that sulfur improved the modulus of rupture from a nominal 1000 psi (6.89×10^6 Pa) to more than 3000 psi (2.7×10^7 Pa). The results of that initial program were published in June 1971 in EPA Report No. 11024EQE.

In 1974, a demonstration grant was awarded to the then Texas Water Quality Board (TWQB) with SwRI as the contractor to the TWQB. This second program involved the cooperation of several Texas cities that provided demonstration sites where various types of impregnated concrete sewer pipe were placed under test. Gifford-Hill Pipe Co. of Dallas donated all of the concrete pipe for the program, as well as transportation of the pipe to SwRI for treatment and then from SwRI to each test site. In addition, numerous manufacturers supplied complimentary fiberglass manholes, PVC pipe, ductile iron pipe, plastic manhole rings, and heat-shrinkable jointing materials. Under this second program, approximately 1400 linear feet (427 m) of concrete pipe in diameters of 8, 10, and 12 inches (20.3, 25.4, and 30.5 cm) was impregnated. Between July and December of 1975, this impregnated pipe was installed in four sites in three Texas cities, and these lines were monitored for the duration of the project. Results of this second program were published in Report EPA-600/2-80-009 in March 1980.

The subject follow-on program, Cooperative Agreement No. CR807356010, was initiated in June 1980 to address six areas: (1) continued inspection of the lines, (2) retrieval of failed lines, (3) the investigation of impregnation parameters, (4) consultation on the construction of a pilot impregnation facility, (5) operation of the pilot plant, and (6) establishment of economics for the impregnation process.

Budget cuts early in the program limited this study to monitoring the in-service lines. Accordingly, this report is limited to presenting the monitoring results, although data from the earlier projects is included to facilitate a complete understanding of the overall program.

2. CONCLUSIONS

1. Of the different types of impregnated pipe under test, the HF-impregnated pipe appears to be performing better than the sulfur-impregnated pipe.

2. In the past two years, significant corrosion has occurred in the sulfur-impregnated pipe installed at the Harlingen site. Although the exact cause for this dramatic increase in corrosion is not known, it is thought to be directly linked to a change in operating conditions of the lift station immediately downstream of the test site.

3. In Dallas and Beaumont, there is not a significant difference between the corrosion of the concrete control and the other types of impregnated pipe, although conditions at the Dallas site appear more severe than those at the Beaumont site.

4. The slightly plasticized sulfur appears to be performing as well as the sulfur containing bactericide. This could be significant and is discussed in more detail in the report.

3. RECOMMENDATIONS

1. Monitoring of the impregnated lines should continue. The lines in Harlingen and Dallas should receive particular attention over the next few years because corrosion appears to be more severe in these two locations.

2. Studies should be initiated to determine the strength improvements possible with pipe larger than 18 in. (45.7 cm) diameter. This effort should include the use of the SULPHLEX® * materials, which are highly plasticized sulfur compositions, rather than sulfur because of the anticipated better performance, as discussed in the report.

3. These additional studies should also investigate a change in cement/aggregate ratios, as well as the use of steel-reinforced and non-reinforced pipe.

4. A semi-commercial pilot plant to impregnate large diameter pipe should be built so that operating parameters can be established and comprehensive cost analyses can be conducted.

*SULPHLEX® - Registered trade mark of Southwest Research Institute

4. MEASUREMENTS

Periodic inspections of the lines in Harlingen, Dallas, and Beaumont have been made since 1975. A set of inside calipers are used to simply measure the vertical inside diameter of the pipe being inspected. The measurements were taken in centimeters but are reported in both English and metric units in Tables 1 through 3 for the various types of pipe in each location. Please refer to these tables for the following discussion.

Harlingen

It was anticipated that Harlingen would be the site of greatest corrosion because specimens placed there earlier in preliminary inspections indicated corrosion rates could be as high as 0.125 in. (0.3 cm) per year. This has not been the case, however, and in 10 years, the total wall loss or corrosion has been 0.125 in. (0.3 cm) for the concrete control. The HF-treated pipe shows 0.125 in. (0.3 cm) of corrosion, and the other types show approximately 0.4 in. (1 cm) for corrosive loss. For those materials marked Sulfur-1, the sulfur used in the impregnation process contained 0.5% sodium pentachlorophenate as a bactericide. The Sulfur-2 material contained 2% of dicyclopentadiene as a plasticizer.

Dallas

Evaluation of the Dallas site data indicates the concrete control, the Sulfur-2, and the HF/S (double treated with HF and sulfur) have suffered approximately 0.4 in. (1 cm) corrosive loss compared to half that for the HF-treated pipe. The diameter decrease reported for the ductile iron pipe is attributed to a sulfating of the cement liner, similar to that encountered with some of the concrete joints. The decrease of the PVC pipe diameter is attributed to deformation under load of the backfill, which is apparent from TV monitoring.

Beaumont

From the Beaumont data, it would appear that both types of sulfur-impregnated pipe are somewhat better than the HF-treated and concrete control. Of all the sites, Beaumont appears to have the least corrosive conditions.

It is also interesting to note that from December 1982 to January 1985, significant corrosion occurred at the Harlingen site. During this time a change in operation was made at the lift station immediately downstream of the test site. Whereas in the past, the pump in the lift station had run continuously, allowing the lines to flow half full or less, during the last two years, the pump has been cycled to the point that a 3- to 4-ft head of sewage is maintained in the lines and manholes.

TABLE 1. DOMESTIC LINE—HARLINGEN

Internal Pipe Diameter - inches (cm)

Length Installed	Type	Feb. '75	Aug. '76	Feb. '78	Mar. '79	Dec. '80	Dec. '82	Jan. '85
12 ft	Sulfur-1	11.2 (28.4)	11.3 (28.6)	11.2 (28.4)	11.1 (28.2)	11.2 (28.5)	11.2 (28.4)	11.6 (29.5)
24 ft	Sulfur-2	11.9 (30.0)	11.9 (30.3)	12.0 (30.5)	12.1 (30.7)	12.2 (31.0)	12.2 (30.9)	12.3 (31.3)
12 ft	HF/S	11.4 (28.9)	11.4 (29.0)	11.4 (29.0)	11.5 (29.2)	11.6 (29.4)	11.4 (28.9)	11.8 (29.9)
12 ft	HF	11.6 (29.5)	11.6 (29.4)	11.5 (29.3)	11.6 (29.4)	11.5 (29.2)	11.9 (30.0)	11.7 (29.8)
12 ft	Concrete Control (reinforced)	11.6 (29.5)	11.6 (29.5)	11.7 (29.6)	11.5 (29.2)	11.4 (28.9)	11.6 (29.4)	11.7 (29.8)

TABLE 2. DOMESTIC LINE-SHOWBEND-DALLAS SITE

Internal Pipe Diameter - inches (cm)

Length Installed	Type	Jul. '75	Jul. '76	Jun. '78	Mar. '79	May '81	Aug. '82	Aug. '84	Mar. '85
57 ft	PVC	9.7 (24.7)	9.6 (24.4)	9.6 (24.4)	9.6 (24.4)	9.5 (24.2)	9.6 (24.4)	9.6 (24.5)	9.6 (24.3)
75 ft	Ductile Iron	10.4 (26.4)	10.4 (26.4)	10.4 (26.3)	10.3 (26.2)	10.2 (26.1)	10.4 (26.4)	10.4 (26.3)	10.2 (26.1)
130 ft	Sulfur-2	10.1 (25.6)	10.0 (25.5)	10.3 (26.2)	10.4 (26.3)	9.9 (25.1)	10.5 (26.6)	10.4 (26.3)	10.4 (26.4)
131 ft	HF	10.0 (25.3)	10.1 (25.7)	10.0 (25.5)	10.2 (25.9)	10.2 (25.8)	10.2 (25.8)	10.2 (25.8)	10.2 (25.8)
71 ft	HF/S	10.0 (25.5)	10.1 (25.6)	10.0 (25.3)	10.2 (25.8)	10.1 (25.7)	10.2 (26.0)	10.2 (26.1)	10.4 (26.3)
60 ft	Concrete Control (Non-reinforced)	10.0 (25.3)	10.2 (25.9)	10.4 (26.5)	10.4 (26.3)	10.2 (25.9)	10.2 (26.1)	10.5 (26.6)	10.4 (26.3)

TABLE 3. DOMESTIC LINE-BOB ST.-BEAUMONT

Internal Pipe Diameter - inches (cm)

Length Installed	Type	Jul. '75	Jul. '76	Jun. '78	Mar. '79	Jun. '81	Jul.' 82	Mar. '85
52 ft	Sulfur-2	9.9(25.2)	9.9 (25.2)	10.3 (26.1)	10.0 (25.3)	10.0 (25.5)	10.1(25.6)	10.0 (25.5)
52 ft	Sulfur-1	10.0 (25.4)	10.0 (25.5)	10.2 (25.8)	10.1 (25.5)	10.0 (25.7)	10.0 (25.5)	10.0 (25.7)
52 ft	HF	9.9 (25.2)	10.0 (25.3)	10.2 (25.9)	10.0 (25.3)	10.0 (25.4)	10.1 (25.6)	10.0 (25.7)
52 ft	Concrete Control (Nonreinforced)	10.0 (25.4)	10.0 (25.5)	10.2 (25.8)	10.0 (25.4)	10.0 (25.5)	10.2 (25.9)	10.2 (25.9)

It is thought that this liquid head of slightly alkaline sewage may have leached the sulfur from the pipe surface and allowed corrosion to occur. If this has been the case, then new developments at SwRI within the last several years could eliminate this problem. Sulfur is well known for its acid resistance, but sulfur has poor resistance to alkali. Even slightly modified sulfur is attacked by alkali. SULPHLEX, however, which is a highly plasticized sulfur product, has demonstrated excellent resistance to both acids and alkali and, as such, should not be affected by the alkaline nature of sewage. Also, from the data thus far, the slightly plasticized sulfur is performing as well as the sulfur containing the bactericide. If this indeed is true, then SULPHLEX products should offer superior properties and offer good resistance to both alkaline conditions and bacterial attack.

Another consideration that must be taken into account in interpreting the data is the manner in which impregnation occurred in the pipe joints. In the Packer-head process of manufacturing pipe, a movable mandrel disperses the concrete in the pipe mold and then mechanically works the inside diameter to give a nearly impervious surface. As a result, impregnation of the pipe wall must progress from the outside diameter toward the inside diameter. If total saturation is not achieved, the corrosion rate for impregnated pipe will be the same as for the concrete control until the impregnated surface is exposed. Thus, with the exception of the Harlingen site, it is difficult to establish a significant difference in corrosion rates. Continued monitoring will be required before any definitive conclusions can be drawn, however.

5. DISCUSSION

Since these programs of impregnation were initiated in 1970, a number of significant changes have occurred in the sewer pipe industry. There has been a tremendous upsurge in the use of PVC plastic sewer pipe. As a result, very few concrete pipe companies manufacture concrete sewer pipe in diameters smaller than 18 inches. Likewise, the fiberglass manholes are replacing concrete and brick manholes. Principal reasons for the shift to PVC pipe include longer, lighter weight joints, good corrosion resistance, and good flow characteristics. Dallas, Beaumont, and Harlingen now use PVC exclusively in their smaller lines. As a result there is no longer any interest in the impregnated concrete pipe in these smaller diameter lines. Likewise, the fiberglass manholes that were originally introduced in these cities at the beginning of this program are used very extensively, if not exclusively, today. A second detrimental factor for concrete sewer pipe has been the increased cement and steel costs brought about by the higher energy costs. Consequently, many concrete pipe companies are beginning to look to other materials for pipe manufacture.

Impregnation, however, still offers considerable potential for the large diameter pipe, particularly if significant strength improvements are a by-product. To reduce overall costs, it would appear that two approaches could be used. In the first, the cement/aggregate ratio could be reduced, with impregnation restoring or improving the concrete strength. The second approach would be to keep the cement/aggregate ratio as it is but reduce or eliminate the steel reinforcing, again the impregnation greatly increasing the concrete strength. However, considerable study would be required to determine the optimum conditions, both mechanically and economically. Any future studies should include the SULPHLEX family of materials because of the improved alkali resistance over elemental sulfur or slightly modified sulfur. Impregnation could also provide advantages in the smaller diameter pipe.

As well as PVC pipe performs, it is not without problems. Because it is lightweight, the lines shift and do not hold the grade. As a result grease plugs are more common in these plastic lines. Extreme care is required in cleaning these lines because the metal cables used to pull the cleaning devices have been known to cut through the top, sides, and bottom of the plastic pipe, depending on the type and degree of realignment. In addition, on the PVC line installed in Dallas, the TV camera has progressively shown a pointed rock bearing on the top of the plastic pipe. This rock in the backfill is causing a deformation and in the next several years will likely penetrate the plastic pipe itself.

Further, for the near term, energy costs and availability appear to be stable. In the future, however, should energy costs again escalate, plastic pipe, cement, and steel prices will rise also.

Impregnation offers an alternative at a cost advantage.